Modified Whitening Rotation based Joint Semi-blind Channel and Data Estimation Scheme for Rayleigh Flat Fading MIMO channels

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Abstract— **In this paper, we propose a novel joint semi-blind channel and data estimation technique based on Whitening Rotation (WR) method for Rayleigh flat fading Multiple Input Multiple output (MIMO) channel using different receiver antennas combinations. Here we divide newly proposed technique in three steps. In the first step, we use conventional Whitening Rotation based semi-blind channel estimation technique, where MIMO channel matrix H can be decomposed as $H=WQ^{H}$. Whitening matrix W can be estimated blindly using second order statistical information of received data and unitary rotation matrix Q can be estimated exclusively using Orthogonal Pilot Maximum Likelihood (OPML) algorithm. In the second step, data symbols can be estimated using estimated channel H and received output data by applying maximum likelihood data estimation method. Finally in the third step, Q can be re-estimated as a Q_{new} using OPML algorithm by considering estimated blind data symbols itself as a pilot symbols for more statistical information of unitary matrix and perform final channel estimation $H_{final}=W Q_{new}^{H}$. Simulation results are presented under 4-PSK data modulation scheme for two transmitters and different combinations of receiver antennas to support proposed novel technique and they demonstrate improved BER performance compared to conventional WR based optimal technique and Rotation Optimization Maximum Likelihood (ROML) based suboptimal semi-blind channel estimation technique.**

Keywords- Multiple Input Multiple Output, Orthogonal Pilot Maximum Likelihood technique, Whitening Rotation based Semi Blind Channel Estimation , Rotation Optimization Maximum Likelihood technique

I. INTRODUCTION

A Multiple Input Multiple Output (MIMO) communication system uses multiple antennas at the transmitter and receiver to achieve numerous advantages. Traditionally, antenna arrays have been used at the transmitter and the receiver to achieve array gain, which increases the output SNR of the system. More recently, ways of using multiple antennas has been discovered to achieve diversity and multiplexing gain by exploiting the once negative effect of multipath. Under suitable conditions, i.e. a scatter rich environment, the channel paths between the different transmit and receive antennas can be treated as independent channels due to the multipath effects caused by the scatterers. Channel state information (CSI) provides key information for the operation of MIMO wireless communication systems and hence need to be estimated accurately. Many channel estimation algorithms have been developed in recent years. In the literature [11-14], MIMO channel estimation methods can be classified into three classes: training based, blind and semi-blind. For pure training based scheme, a long training is necessary in order to obtain a reliable channel estimate, which considerably reduces system bandwidth efficiency. In Blind methods, no training symbols are used and channel state information is acquired by relaying on the received Signal statistics [17-20], which achieves high system throughput requiring high computational complexity. Semi-blind channel estimation approaches as a combination of the two aforementioned procedures [21-23], with few training symbols along with blind statistical information, such techniques can solve the convergence problems and high complexity associated with blind estimators. Extensive work has been done later by Slock et. al. [3-4], where several semi-blind techniques have been reported. Whitening Rotation (WR) based semi blind technique with Orthogonal Pilot Maximum Likelihood (OPML) [5-8] has shown very good performance compare to other sub-optimal techniques and training based channel estimation techniques. In WR method, channel matrix H is decomposed as whitening matrix W and unitary rotation matrix Q. Whitening matrix W is estimated using received output data blindly and Q is estimated using orthogonal pilot maximum likelihood (OPML) algorithm.

Here we have developed a novel joint semi-blind channel and data estimation technique which is described by three basic steps given below

Step 1: Initial channel estimation is performed using Whitening Rotation (WR) based semi-blind channel estimation technique as $H=WQ^{H}$.

Step 2: Given channel knowledge (estimate) and received output, perform data estimation using maximum likelihood method.

Step 3: Estimate unitary rotation matrix Q_{new} again by Considering estimated blind data symbols itself as pilot symbols and perform final channel estimation as $H_{final}=W Q_{new}^{H}$.

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This novel technique performs better than conventional WR based optimal and rotation optimization ML (ROML) based suboptimal semi-blind channel estimation techniques. The remainder of this paper is organized as follows. The second section describes the system model. The estimation algorithms with proposed techniques are presented in section 3, simulation results and discussion provides in section 4 and section 5 concludes this paper.

II. SYSTEM MODEL

Consider a ûat fading MIMO channel matrix $H \in c^{r \times t}$ where t is the number of transmit antennas and r is the number of receive antennas in the system, and each h_{ij} represents the ûat-fading channel coefficient between the i^{th} receiver and j^{th} transmitter. Denoting the complex received data by $Y \in c^{r \times 1}$, the equivalent base-band system can be modeled as

$$Y(k) = HX(k) + \eta(k) \tag{1}$$

Where $$H = \begin{bmatrix} h_{11} & h_{12} & \cdots & h_{1t} \\ h_{21} & h_{22} & \cdots & h_{2t} \\ \vdots & \vdots & \ddots & \vdots \\ h_{r1} & h_{r2} & \cdots & h_{rt} \end{bmatrix}$$

k represents the time instant, $X \in c^{t \times 1}$ is the complex transmitted symbol vector. η is additive white Gaussian noise such that $\mathrm{E}\{\eta(k)\eta(l)\} = \delta(k,l)\sigma_n^2 I$ where $\delta(k,l) = 1$ if $k = 1$ and 0 otherwise. Also, the sources are assumed to be spatially and temporally independent with identical source power σ_s^2 i.e. $\mathrm{E}\{X(k)X(l)\} = \delta(k,l)\sigma_s^2 I$. The signal to noise ratio (SNR) of operation is deûned as SNR $\frac{\sigma_s^2}{\sigma_n^2}$ Assume that the channel has been used for a total of N symbol transmissions. Out of these N transmissions, the first L symbols are known training symbols X_p and reaming N - L are blind data symbols X_b, Y_p and Y_b are their respective outputs.

III. CHANNEL ESTIMATION TECHNIQUES

A). Whitening Rotation based semi-blind channel estimation

Now consider a MIMO channel $H \in c^{r \times t}$ which has at least as many receive antennas as transmit antennas i.e. $r \geq t$. Then, the channel matrix H can be decomposed as $H = WQ^H$ where $W \in c^{r \times t}$ is also known as the whitening matrix and $Q \in c^{t \times t}$, termed as the rotation matrix, that is unitary i.e. $Q^H Q = QQ^H = I$ As shown in [5], the matrix W can be estimated from the covariance of received data alone. We therefore employ the pilot information to exclusively estimate the rotation matrix Q. This semi-blind estimation procedure is termed as a Whitening-Rotation (WR) scheme. Let the Singular Value Decomposition (SVD) of H be given as $P \sum Q^H$. A possible choice for W is given by $W = P\sum$ and we assume this speciûc choice in the rest of the work. We present next a list of potential assumptions which are employed as appropriate in subsequent parts of the work.

Assumption A. $W \in c^{r \times t}$ is perfectly known at the output.

Assumption B. $X_p \in c^{t \times L}$ is orthogonal i.e. $X_p X_p{}^H = \sigma_s^2 L I_{t \times t}$

Assumption A is reasonable if we assume the transmission of a long data stream (N $\longrightarrow \infty$) from which W can be estimated with considerable accuracy and Assumption B can be easily achieved by using an integer orthogonal structure such as the Hadamard matrix.

$\hat{Q}: c^{r \times L} \rightarrow S$, where $\hat{Q}$ the constrained ML estimator of is Q and S is the manifold of unitary matrices, is obtained by minimizing the likelihood

$$\left\| Y_p - WQ^H X_p \right\|^2 \text{ Such that } QQ^H = I \tag{2}$$

$M = W^H Y_p X_p{}^H$ We then have the following result for the constrained estimation of Q. Under both assumption $\hat{Q}$ the constrained OPML estimate of Q that minimizes the cost function in (2) is given by

$$\hat{Q} = V_M\, U_M^H \text{ Where, } U_M \Sigma_M V_M^H = SVD(M) \tag{3}$$

This technique has been proposed and proved in [5] since this procedure employs assumption B. (orthogonal pilot), which termed as the OPML estimator. The above expression (3) thus yields a closed form expression for the computation of $\hat{Q}$, the ML estimate of Q. The channel matrix H is then estimated

as $$\hat{H} = W\, \hat{Q}^H. \tag{4}$$

B). Rotation Optimization Maximum likelihood (ROML) based semi-blind channel estimation

To avoid the complexity involved in the full computation of the optimal ML solution, we propose a simplistic ROML procedure for the sub-optimal estimation of Q, thus trading

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complexity for optimality. The ûrst step of construct modified cost function

$$\min_{Q}\left\|\tilde{W}\,Y_p - Q^H X_P\right\|^2 \quad \text{Where } QQ^H = I \tag{5}$$

$\tilde{Y} = \tilde{W}\,Y_p$ Is the whitening pre-equalized data. Several choices can then be considered for the pre-equalization ûlter $\tilde{W}$. A robust MMSE pre-ûlter is given as

$$\tilde{W}_{MMSE} = \sigma_s^2 W^H(\sigma_s^2 WW^H + \sigma_n^2 I)^{-1} \tag{6}$$

Defining $D \triangleq \tilde{W}\,Y_p X_p^H$, the cost minimizing $\hat{Q}$ for the modifying cost is given as

$$\hat{Q} = V_D U_D^H \quad \text{Where} \quad U_D S_D V_D^H = SVD(D) \tag{7}$$

The channel matrix H is then estimated as $\hat{H} = W\,\hat{Q}^H$.

C). A novel joint semi-blind channel and data estimation technique (proposed new-WR technique)

Initial channel estimation is accomplished by WR based technique. Now based on that channel estimate $\hat{H}$, perform data estimation X_{best} as

$$X_{best} = \hat{H}^H\, Y_b \tag{8}$$

Further in X_{best} itself consider as pilot symbols, Y_b is received output and again perform OPML algorithm as

$$\left\|Y_b - WQ_{new}^H X_{best}\right\|^2 \quad \text{Such that } Q_{new}Q_{new}^H = I \tag{9}$$

And M_b is denoted as

$$M_b = W^H Y_b X_{best}^H \tag{10}$$

Under both assumption $\hat{Q}_{new}$ the constrained OPML estimate of Q_{new} that minimizes the cost function in (9) is given by

$$\hat{Q}_{new} = V_{Mb}\, U_{Mb}^H \quad \text{Where, } U_{Mb}\,\Sigma_{Mb}\, V_{Mb}^H = SVD(M_b)$$

(11)

So final channel estimation H_{final} is given by

$$\hat{H}_{final} = W\,\hat{Q}_{new}^H. \tag{12}$$

IV. SIMULATION RESULTS

Extensive computer simulations have been conducted to demonstrate the performance of proposed novel technique compared with conventional WR based optimal and ROML based suboptimal techniques. In simulation scenarios the 4-PSK data modulation scheme is used and flat fading Rayleigh MIMO channels H are generated. We consider alamouti coded 2×N MIMO (where N= 4, 6, 8 receiver antennas) systems with 4 orthogonal pilots and first 100 blind data symbols among 20000 pair transmitted symbols used. Result shows in figures depicts that novel technique outperforms others by 2 dB to 3 dB performance improvements due to more statistical information of unitary matrix Q by using whole burst of estimated data itself as pilot symbols in OPML algorithm. It achieves nearby performance compared to perfect CSI (channel state information). Now in first simulation setup shown in figure 1, we have used 2 transmitter and 4 receiver antennas. At 2 dB SNR, Bit error rate (BER) is 0.0853 for ROML, 0.0619 for WR, 0.0242 for new technique and 0.0213 for perfect CSI.

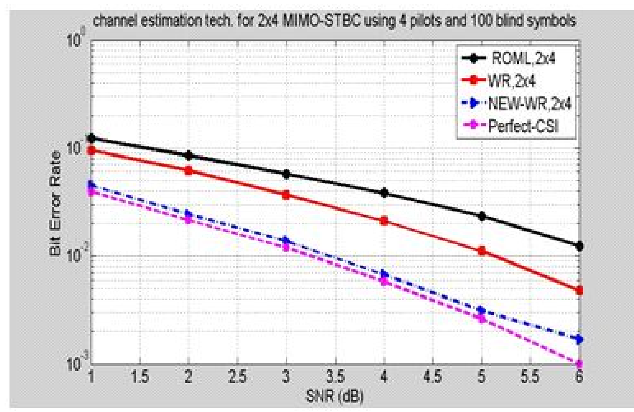

Fig. 1 BER Vs SNR for diff. channel estimation techniques using 4 pilot symbols and 100 Blind symbols using 2 transmitter and 4 receiver antennas for 4 PSK modulation scheme

In the second simulation setup shown in figure 2, we have used 2 transmitter and 6 receiver antennas. At 2 dB SNR, Bit error rate (BER) is 0.0303 for ROML, 0.0207 for WR, 0.0069 for new technique and 0.0057 for perfect CSI.

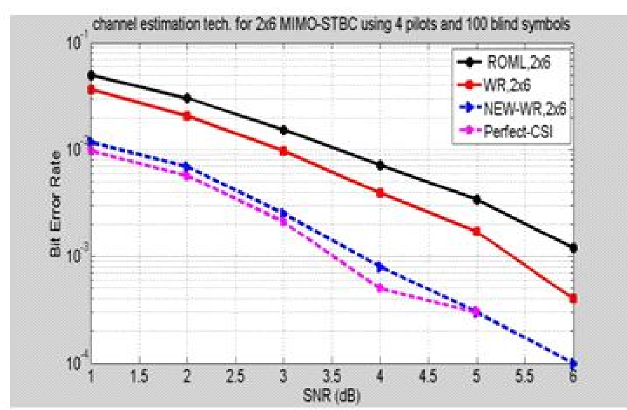

Fig. 2 BER Vs SNR for diff. channel estimation techniques using 4 pilot symbols and 100 Blind symbols using 2 transmitter and 6 receiver antennas for 4 PSK modulation scheme

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Third simulation setup shown in figure 3, in that we have used 2 transmitter and 8 receiver antennas. At 2 dB SNR, Bit error rate (BER) is 0.0110 for ROML, 0.0079 for WR, 0.0016 for new technique and 0.0013 for perfect CSI.

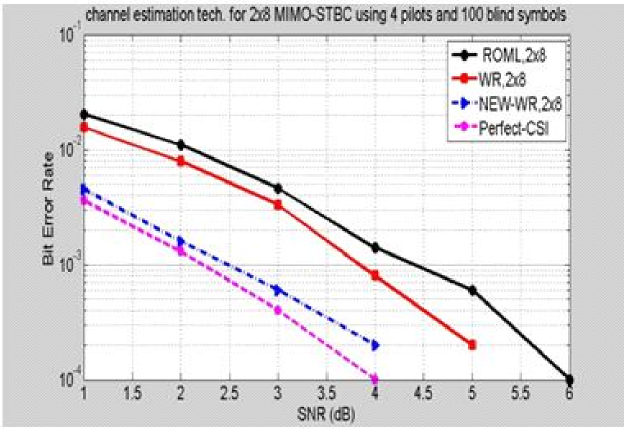

Fig. 3 BER Vs SNR for diff. channel estimation techniques using 4 pilot symbols and 100 Blind symbols using 2 transmitter and 8 receiver antennas for 4 PSK modulation scheme

Further with respect to increases in receiver antennas combinations, BER improves 1.5 dB to 2 dB respectively that shows in figure 4.

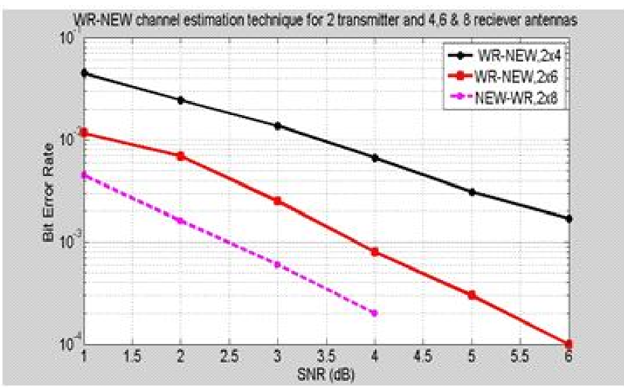

Fig. 4 BER Vs SNR for proposed channel estimation technique using 4 pilot symbols and 100 Blind symbols using 2 transmitter and diff. receiver antennas for 4 PSK modulation scheme

V. CONCLUSION

A new joint semi-blind channel and data estimation technique is proposed and investigated for Rayleigh faded MIMO channel matrix H using different receiver antennas combinations. Employing these results, we have demonstrated that proposed novel technique performs better than conventional WR and ROML based semi-blind channel estimation techniques. Further with increases in receiver antennas, BER improves.

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